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Effect of phosphorus and potassium levels on productivity and profitability of soybean (*Glycine max* L.)

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Abstract
A field experiment was conducted at Crop Research Centre, School of Agriculture, ITM University, Gwalior – 474001 (M.P.) during the *kharif* season 2022 to study the effect of phosphorus and potassium levels on yield and economics of soybean (*Glycine max* L.) in factorial randomized block design (FRBD) with three replications and a absolute control. The variety JS-1050 was sown along with phosphorus levels (0, 20, 40 and 60 kg ha^{-1}) and potassium levels (0, 15, 30 and 45 kg ha^{-1}). The soil of the experimental field was sandy loam in texture, having a pH of 7.35, organic carbon of 0.41%, and available nitrogen (178.03 kg ha^{-1}), phosphorus (24.45 kg ha^{-1}) and potassium (382.15 kg ha^{-1}) respectively. The result of the experiment revealed that an increase in the application of phosphorus and potassium had significantly increased the growth, yield and quality of soybean. Among the phosphorus levels 60 kg ha^{-1} will be significantly higher over the remain phosphorus levels followed by 40 kg ha^{-1} then 20 kg ha^{-1}. And among the potassium levels 45 kg ha^{-1} will be at par with 30 kg ha^{-1} both surpassed over 15 kg ha^{-1}. On the basis of economics, the highest net return (Rs. 85691 ha^{-1}) was recorded under the combination of 60 kg ha^{-1} P_2O_5 + 45 kg ha^{-1} K_2O has been recorded with the Benefit-cost ratio (Rs. 2.05 re^{-1} invested).

Keywords: phosphorus, potassium, profitability, soybean, *Glycine max* L.

Introduction
Soybean is a versatile and globally significant legume that has gained prominence as a crucial crop in agriculture. Native to East Asia, soybeans have a rich history dating back thousands of years, and today they play a vital role in the global food supply, livestock feed, and industrial applications. Farmers generally use high analysis fertilizers, which add a few major nutrient into the soil, whereas, plants absorb all necessary nutrients for their growth and development. The sharp increase in soybean yields is partly due to the balanced fertilization and good cultural practices (Tomar, 2004) [8]. One of the main causes in decline the soybean production is imbalanced fertilization of nutrients (N, P and K). Phosphorus is the main nutrient contributing to the stabilization of biological nitrogen in soybean and removes 28 kg of P/ha from the soil. Phosphorus encourages nodule formation and rhizobial activity in legumes, which aids in N_2 fixation. It boosts the effectiveness of using water, enhances bean flavour, storage quality, and skin hardness. As phosphorus plays a role in photosynthesis, respiration, energy storage and transfer, cell division and enlargement, it has been shown to be important for growth, development and yield of soybean. Potassium (K) is one of the important nutrient elements and plays a major role in crop growth and development, modifies abundant enzyme activations, controls the cell osmo-regulation and the stomatal movement of photosynthesis. In addition, potassium also can alleviate harmful effect of abiotic stress in crops. The scarcely resource of potassium mine and the inefficiency of fertilizer use have effected on the improvement of crop production.

Materials and Methods
The experiment was conducted at Crop Research Centre, School of Agriculture, ITM University, Gwalior – 474001 (M.P.) during the *kharif* season 2022. Soil of the experimental field was sandy loam, having pH 7.35, organic carbon 0.41%, EC (dsm^{-1}) 0.22%, and 178.03, 24.45 and 382.15 kg ha^{-1}, available N, P and K respectively. The experiment contain ten treatment combination, *viz.* T_1: 0 kg ha^{-1} of P_2O_5 + 0 kg ha^{-1} of K_2O (Control), T_2: 20 kg ha^{-1} of P_2O_5 + 15 kg ha^{-1} of K_2O, T_3: 20 kg ha^{-1} of P_2O_5 + 30 kg ha^{-1} of K_2O, T_4: 20 kg ha^{-1} of P_2O_5 + 45 kg ha^{-1} of K_2O, T_5: 40 kg ha^{-1} of P_2O_5 + 15 kg ha^{-1} of K_2O, T_6: 40 kg ha^{-1} of P_2O_5 + 30 kg ha^{-1} of K_2O, T_7: 40 kg ha^{-1} of P_2O_5 + 45 kg ha^{-1} of K_2O, T_8: 60 kg ha^{-1} of P_2O_5 + 15 kg ha^{-1} of K_2O, T_9: 60 kg ha^{-1} of P_2O_5 + 30 kg ha^{-1} of K_2O, T_{10}: 60 kg ha^{-1} of P_2O_5 + 45 kg ha^{-1} of K_2O.

The experiment was laid-out in a factorial randomized block design with three replications. The recommended dose of nitrogen was applied 20 kg ha^{-1}. Rows of the field were marked with a marker, and sown at the spacing of 45 x 30 cm. The seeds were sown at the depth of 4 cm. The gross plot size was 4.5 x 3.6 m, whereas, the net plot size was 3.9 x 2.7 m. To maintain the appropriate plant population, the gaps were filled 10 days following the sowing. During the crop season application of imazathypr 10% SL herbicide and two manual weeding (40 and 60 days after sowing) were done to manage weeds in the experimental fields. Plants were tagged randomly in the net-plots for recording growth and yield attributes. Net returns generated by a crop, was the amount of money which was left, when cost of cultivation were subtracted from the gross returns which corresponds to the value of the harvested crop. B: C ratio indicates the returns one gets after investing one rupee. It was calculated by dividing the gross returns with the cost of cultivation.

Results and Discussion

Yield attributes

Table 1 clearly illustrates the substantial impact of phosphorus and potassium levels on number of pods plant^{-1}, number of grains pod^{-1}, length of pod (cm), test weight (100 grain). The application of 60 kg ha^{-1} of phosphorus resulted in the highest number of pods^{-1} (42.61), number of grains^{-1} (2.88), length of pod (3.99 cm), test weight (11.60 g) significantly surpassing the 20 kg ha^{-1} levels. The application of 45 kg ha^{-1} of potassium resulted in the highest of yield attributes and significantly superior over the 30 kg and 15 kg ha^{-1}. The results suggest that phosphorus and potassium levels independently play pivotal roles in various aspects of soybean growth and development, from pod and grain production to pod length, test weight, and overall crop yield. Their combined presence did not lead to significant synergies or antagonisms in these contexts. Thus, optimizing phosphorus and potassium levels individually appears to be essential for maximizing soybean crop quality and yield.

Table 2 provides valuable insights into the impact of phosphorus and potassium levels on grain yield, straw yield and harvest index (%). Specifically, the application of 60 kg ha^{-1} of phosphorus resulted in the highest grain yield (2668.22 kg ha^{-1}), straw yield (4333.33 kg ha^{-1}) and harvest index (38.08%) significantly surpassing the yields obtained with 40 kg and 20 kg ha^{-1}. Regarding potassium levels both 45 kg and 30 kg ha^{-1} performed equally well yielding higher yields compare to 15 kg ha^{-1}. These suggest that higher potassium levels are essential for optimizing yield.

Table 1: Effect of phosphorus (P) and potassium levels (K) on yield attributes of soybean

Treatments	Yield Attributes				Yields (Kg ha^{-1})		Harvest index (%)
	Pods/plant	Grains/pod	Pod Length (cm)	100-grain weight	Grain	Straw	
P levels (kgha^{-1})							
20	34.13	2.49	3.01	9.65	2204.11	3682.67	37.42
40	37.05	2.60	3.42	10.56	2356.22	3861.72	37.88
60	42.61	2.88	3.99	11.60	2668.22	4333.33	38.08
S.Em ±	1.05	0.08	0.15	0.31	57.29	104.60	1.02
C.D at 5%	3.11	0.25	0.46	0.93	170.22	310.78	3.04
K levels (kgha^{-1})							
15	35.00	2.38	2.78	9.68	2239.00	3730.67	37.50
30	38.30	2.69	3.69	10.63	2443.56	4042.61	37.63
45	40.49	2.90	3.94	11.49	2546.00	4104.44	38.24
S.Em ±	1.05	0.08	0.15	0.31	57.29	104.60	1.02
C.D at 5%	3.11	0.25	0.46	0.93	170.22	310.78	3.04
Control	29.66	2.07	2.59	7.24	1727.67	2992	36.29
Interaction							
S.Em ±	1.81	0.15	0.27	0.55	99.23	181.17	1.77
C.D at 5%	NS	NS	NS	NS	NS	NS	NS

Economics: The analysis of cost of cultivation, gross returns, net returns, and benefit-cost ratio indicates that the application of 60 kg P ha^{-1} + 45 kg K ha^{-1} consistently outperformed other treatment combinations in terms of economic outcomes. This combination resulted in the highest cost of cultivation (₹ 41702 ha-1) but also yielded the highest gross (₹ 1, 27,563 ha^{-1}) and net returns (₹ 85,861 ha^{-1}), as well as the most favorable benefit-cost ratio (2.06). Conversely, the treatment with no phosphorus and potassium application had the lowest economic returns. These findings underscore the importance of balanced nutrient management for optimizing both crop profitability and sustainability.

Table 2: Effect of phosphorus and potassium levels on economics of soybean

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B-C ratio
T1 (P_0K_0)	37717	78522	40805	1.08
T2 ($P_{20}K_{15}$)	39045	94869	55824	1.43
T3 ($P_{20}K_{30}$)	39469	96778	57310	1.45
T4 ($P_{20}K_{45}$)	39892	99990	60098	1.51
T5 ($P_{40}K_{15}$)	39950	103762	63812	1.60
T6 ($P_{40}K_{30}$)	40374	108838	68464	1.70
T7 ($P_{40}K_{45}$)	40797	110428	69631	1.71
T8 ($P_{60}K_{15}$)	40855	117564	76709	1.88
T9 ($P_{60}K_{30}$)	41279	125821	84542	2.05
T10 ($P_{60}K_{45}$)	41702	127563	85861	2.06

Conclusion

Based on the experimental condition, it is concluded that for achieving a higher yield of soybean, the crop will be fertilized with phosphorus at 60 kg P_2O_5 ha^{-1} along with the potassium 45 kg K_2O ha^{-1} gives the highest grain yield (2668.22 kg ha^{-1}) and straw yield (4333.33 kg ha^{-1}) proved the most remunerative with respect to net returns of (₹ 85861.00) and benefit-cost ratio (₹ 2.06 re^{-1} invested).

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